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USAF PILOT PROFICIENCY: AN ANALYSIS OF ACTUAL AND SIMULATED FLIGHT DATA

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The purpose of this study was to determine whether USAF pilot proficiency has been reduced since the implementation of energy conservation measures (1972). These conservation measures resulted in reduced actual flying and the increased use of flight simulators. A census of total flight hours, aircraft accidents, and simulator usage data was analyzed for a defined population of pilots using direct comparison, analysis of variance, and regression analysis techniques. Pilot improficiency (inverse of proficiency) was defined as the average cost per aircraft accident per given period of time. This cost was used to quantify pilot proficiency and a prediction model was formulated to determine its level when given flight and simulator hour variables. Other variables, such as phase of flight, aircraft type, pilot-in-command/instructor pilot time, and major command assignment were examined in the tests of the research hypotheses. The conclusions given the data of the study are: (I) There has been a decrease in total flying proficiency, (II) The decrease in proficiency can be attributed to reductions in actual flight hours and to increases in the use of flight simulators as a substitute for actual flight.

SLSR 20-76B

USAF PILOT PROFICIENCY: AN ANALYSIS OF ACTUAL AND SIMULATED FLIGHT DATA

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

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September 1976

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CHAPTER I

INTRODUCTION

In recognition of our national energy goals and to reduce the cost of training, the Air Force is moving toward replacing some flight training with simulation. Air Force policy has been stated as follows:

> Department of Defense guidance has been issued directing all the Services to strive for a 25% reduction in flying hours by the end of Fiscal Year 1981 through increased use of simulation. In addition to energy considerations, other issues such as restricted airspace, environmental and ecological impacts, safety and aircraft attrition, dictate that the Air Force aggressively pursue increased use of flight simulators.
>
> To meet this ambitious goal will require an investment of over one and one-half billion dollars over the next five years to obtain the sophisticated training devices that are required.
>
> Mission simulators will aid greatly in reducing the amount of flying time required while maintaining, and in many cases improving, force readiness [6:27].

STATEMENT OF PROBLEM

Flight simulation is purported to be a viable alternative to actual flight for maintaining pilot proficiency. Proponents of flight simulators contend that state-of-the-art simulators provide both cost effectiveness and the necessary realism-in-training to maintain the desired level of pilot proficiency (5:1). Opponents of flight simulation

as a replacement for actual flight contend that an adequate level of proficiency can best be maintained through hands-on-training in the actual medium, a key factor being the inability of flight simulators to provoke the psychological stress associated with actual flight (9:10).

Brigadier General Norman C. Gaddis, Deputy Director of Operations and Readiness, DCS/Plans and Operations, said recently in a talk to the Naval Training Equipment Center Industry Conference in Orlando, Florida:

> The advocates of more simulation and less flying are riding on a strong wave of concern over increasing cost of fuel, but funds for simulators will have to compete with other Air Force programs and will have to be justified either on a very strong case of improved force readiness or by the offer of savings resulting from flying hour reductions. There are some who believe that flying hours are inevitably going to be reduced. If that is true, then simulation may be our only alternative to reduced force readiness. Simulation then may be likened to false teeth. Dentures are not a substitute for teeth, they are an alternative for no teeth. Simulation may be an alternative for no flying. The distinction may be fine, but I think the analogy holds.
>
> However, there is a rising concern in the Air Force over our ability to meet the flying hour reduction goal. This concern is most prevalent with our fighter force. A significant factor in the effectiveness of our fighters is the sortie rates that can be generated. Sortie rate is much dependent upon the efficiency of the total ground support, supply, administrative services, maintenance and logistics system. To be efficient, this system has traditionally needed considerable exercise. Uncompensated flying hour reductions, for whatever reason, will impact adversely upon the system to operate efficiently and affectively. We must apply the "systems approach" to our training concepts to insure that some training problems are not created as others are solved [7:1].

This thesis effort will take an objective look at simulator hours, flying hours and pilot proficiency to determine if there are trends that indicate reduced pilot skills since the implementation of energy conservation measures (1972), which dictated increased substitution of simulator training for actual flight training.

DEFINITION OF TERMS

Common Aircraft

Inventories of similar types of aircraft.

Energy Conservation Measures

Measures taken to conserve fuel, precipitated by the recognition of serious reductions in energy sources in 1972 (17:144).

Fidelity

Accuracy of simulation (10:3-9). The degree to which the simulator incorporates and displays features such as visual, aerial, and kinesthetic cues which foster high-learning transfer on complex tasks.

Flying Proficiency

Acquired skills necessary to safely accomplish flight mission requirements.

JUSTIFICATION FOR RESEARCH

One of the primary objectives of a peacetime military force is to maintain a state of proficiency through training to permit an instantaneous and decisive response to any global threat (12:22). In order to insure this defense posture, the degree of proficiency of our forces must be adequately assessed and adjusted where necessary. Given the constraints of energy conservation and cost effectiveness, this research will examine pilot proficiency and the use of flight simulators as a substitute for actual flight.

In recent years the Air Force has made significant reductions in aircrew flying hours and has restructured the aircrew force in response to governmental demands for more effective management of fiscal and natural resources. The Government Accounting Office (GAO) previously reported to the Congress that the military services could lower costs and increase pilot proficiency by making greater use of flight simulators (8:4). The report cited the potential cost savings if flying were reduced and pointed out that increased use of simulators could help ease projected fuel shortages and enhance the safety and effectiveness of pilot training programs. As a result, the Air Force goal is to reduce aircraft flying hours 25 percent by the end of FY 1981. This goal will be realized through the increased emphasis on and greater use of flight simulators as a supplement to aircrew training in maintaining flying proficiency (14:4).

Currently, the Air Force's inventory of simulators consists of devices that vary considerably in design, complexity, realism, and training purposes. In the late 1940s, analog computers were used to try to simulate certain cockpit and flight characteristics of a particular airplane. More sophisticated simulators have since been developed which use digital computers and modern electronics technology to produce more realistic flight dynamics (fidelity), such as motion, visual, and instrumentation (5:12). These simulators possess the entire complement of integrated systems necessary to accomplish almost total mission requirements. The disparity of complexity among existing simulators points out a fundamental acquisition problem, which is the lack of knowledge concerning how complex and costly simulator hardware must be in order to provide effective flying training for different missions.

> Air Force simulator acquisition is being driven more by available technology than by requirements based on scientific research findings. For example, more data are required concerning the kind and amount of motion required and the extent and fidelity of visual simulation necessary to achieve effective training in different flight regimes [14:4].

Proponents of flight simulators contend that state-of-the-art simulators are both cost effective and provide the necessary realism-in-training to maintain the desired level of pilot proficiency (2:E-76). This contention has given impetus to simulator design and development.

The Comptroller General lists the following major simulator projects affecting large multiengine aircraft:

MAC is requesting funds for incorporating visual systems, similar to the one used in transition training at Altus AFB, Oklahoma on all C-5 and C-141 aircraft simulators.

SAC has formalized requirements for a B-52 refueling part-task trainer and a related KC-135 boom operator trainer with visual attachments.

SAC is developing plans and requirements for current state-of-the-art simulators with visual systems and 6° of motion[1] for both the B-52 and KC-135 aircraft.

Tactical Air Command has established requirements for 10 new C-130 flight simulators with 6° of motion and a flexible visual system having a wide enough field of view to perform take-off, enroute, approach, and landing tasks.

Air Training Command is constructing a navigation simulator (designated the T-45) complex at an estimated cost of $21 million for use in Undergraduate Navigator Training at Mather AFB, California. A simulator (designated the T-5) for electronic warfare training was accepted by Air Force at Mather in November in 1973 [5:39].

Air Training Command is proposing the TS-2 and TS-3 for future Undergraduate Pilot Training.

> The TS-2 simulator is considered for near term (1977) application in the instrument phase. The digitally driven six degree-of-freedom (DOF) motion system provides kinesthetic cues and faithful handling qualities. Each member of the IP panel flew state-of-the-art simulators which have six DOF motion systems. . . . The instructor pilots were unanimous in the opinion that simulators of this type employing a visual system as described for the TS-2 could replace <u>all</u> instrument training, both to initial capability and for reinforcement [3:H-35].

The TS-3 simulator is projected for the post-1980 time period. It will have additional capabilities over the TS-2 by use of an extremely wide angle visual scene. It will be used for tasks requiring

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[1]6° of motion includes roll, pitch, yaw, lateral, longitudinal, and vertical movements.

visual cues in the contact, navigation, formation, and specialized phases (3:50-52).

Both the TS-2 and TS-3 are proposed for Undergraduate Pilot Training to significantly reduce actual flight in the T-37 and T-38 aircraft respectively. The associated cost savings are a major driving force in Air Force acceptance of simulator training.

> The cost savings with the TS-2 simulator is $578 million and with the TS-2 and TS-3 simulators the savings are projected to be $848 million. This is due to the combined effect of a lower investment in aircraft and their avionics, a higher terminal value, and a lower annual operating cost [4:I-64].

Although the purported savings, as they are presented, indicate simulators to be the best possible alternatives, an in-depth analysis of the total impact of simulation has not been made. For example, simulator cost studies did not address the affect of simulation on the maintenance learning curve due to reduced hands-on-training for flight maintenance personnel. Cost impact studies did not address increased routine maintenance cost associated with stand-down aircraft (15:1-107).

One area of major concern is the impact of increased simulation on pilot proficiency. This study will specifically address simulation and flying hours as they relate to pilot proficiency.

ACCIDENT STATISTICS AS A MEASURE OF PILOT PROFICIENCY

One of the major objectives of any flight training program is to produce a safe pilot. As stated by Johnson, "The goal is to increase his proficiency to the point where he is a reliable component of the operational system [10:3]." Safety and proficiency are interrelated. Accidents resulting from pilot error can be considered a measure of pilot improficiency, or, a reciprocal measure of proficiency.

For purposes of quantifying pilot errors, accident reports maintained at the Air Force Inspection and Safety Center, Norton AFB, California, were obtained and analyzed. Major aircraft accidents for 1970 through 1975 were analyzed and presented in this report. These years were chosen to represent an equal time distribution before and after the implementation of energy conservation and cost effective measures (1972). For the final comparison, 1970 through 1972 will be compared with 1973 through 1975. Only major aircraft accidents resulting from pilot errors were analyzed. To present conservative figures, only major aircraft accidents committed by pilots with over 700 hours total first pilot/instructor pilot time were considered. Seven hundred hours is consistent with Air Training Command's definition of an experienced pilot. To avoid errors in comparing the cost of 1970 inventory aircraft with

different and more expensive aircraft of later vintage, only common aircraft were considered. Additionally, accidents in which battle damage was a contributing factor were not considered.

Total flying time for the period considered was reduced by approximately 10% by 1975 due to increased commitments in Southeast Asia plus implementation of energy conservation and cost effective measures (10). This factor was not considered in the analysis, resulting in more conservative figures. Also, the accident costs figures presented were converted to 1970 dollars by using price deflators published in Economic Indicators (July 1976). The following is a list of the price deflators used in costs conversions:

Year	Deflator
1970	0
1971	2.7
1972	3.3
1973	6.2
1974	11.0
1975	9.2

Converting all costs to 1970 dollars negates the affect of inflation and thus allows a direct comparison of the costs of pilot errors which resulted in major aircraft accidents.

CHAPTER II

RESEARCH METHODOLOGY

Overview of Research

Cause: Cost Effectiveness / Energy Conservation 1972

Effect: Reduced Flying Time

Solution: Increased Use of Simulators

Research: Effect on Pilot Proficiency?

INFORMATION REQUIREMENTS

The following research hypotheses were tested:

(I) There has been a decrease in total pilot flying proficiency since 1972 (ECM implementation).

(II) The decrease in flying proficiency can be attributed to reductions in actual flight hours and to increases in the use of flight

simulators as a substitute for actual flight in maintaining flying proficiency.

To evaluate these hypotheses an analysis of Air Force historical statistical data (1970-1975) was made. The statistical data chosen for analysis are: (1) Aircraft Accident Summaries, (2) Total Flying Hour Reports, and (3) Reports of Total Simulator Hours. Data on aircraft accidents and flying time were obtained from the Air Force Inspection and Safety Center, Norton AFB. The accident data are a census of pilot error accidents for 1970 through 1975. Total Air Force flying time was obtained for the same period. Total simulator hours were obtained from Air Force Logistics Command (ACVMP), Wright-Patterson AFB, and include only those hours in direct support of aircrew training. These statistical data were used to derive an average yearly cost of pilot error (improficiency cost). "Improficiency cost" is used to inversely measure flying proficiency. Pilot flying proficiency has been previously defined as the possession of those acquired skills necessary to safely accomplish flight mission requirements. This information was used to test hypothesis (I). To determine each of the yearly improficiency costs it was necessary to know the total number of major accidents, the total dollar value of the accidents, and the accidents resulting from pilot error in which the pilots involved had more than 700 hours total first pilot/instructor pilot time.

In addition, the association of the total hours flown and the total simulator hours used for each year of the historical period was determined. From the information obtained, the values of these two variables were measured. These variables are defined as follows:

a. AFT_i--The total actual flying time (hours) flown for a given period (i). This variable is a discrete variable of the infinite data level. This variable is utilized in the calculation of (P_i) which is defined below.

b. SFT_i--The total simulated flying time (hours) for a given period (i). This variable is a discrete variable at the infinite data level. This variable is utilized in the calculation of (P_i) which is defined below.

c. P_i--The level of pilot proficiency. (P_i) is a function of (AFT_i + SFT_i). (P_i) is a discrete dependent variable at the ratio level and is utilized in deriving the statistics to be used in hypothesis test (II).

A further analysis of aircraft accidents was made and presented in Chapter IV. This analysis examined the interrelationship of phase of flight, instructor pilot/first pilot time, simulator/flight ratio, aircraft/type and cost of pilot error. These data are computer analyzed using the Statistical Package for the Social Sciences (SPSS).

Chapter V presents a computer model used to predict the level of pilot proficiency (P_i), given flying hours and simulator hours.

The model was developed using historical data and is valid only for the range of observed data.

POPULATION DESCRIPTION

Air Force Pilots

Air Force pilots have undergone rigorous training to insure that at least the minimum acceptable level of pilot proficiency is attained. The initial training is accomplished during 53 weeks of Undergraduate Pilot Training (UPT). Prior to graduation each pilot must satisfactorily demonstrate safety and proficiency in all phases of aircraft flight.

Today, the UPT program represents an amalgamation of user requirements, training, and economic pressures. UPT operates under the philosophy that all graduates should be "universally assignable" (qualified to fly any aircraft in the USAF inventory); therefore, all students receive the same training in the same training vehicles. The training vehicles follow the building-block concept of flight training with the T-41 low-performance aircraft used as a screening device and providing some introductory flight training. The second phase of training is accomplished in the T-37, a medium-performance jet trainer used as a fundamentals vehicle in which all phases of flight are introduced. Finally, the T-38 high-performance jet trainer

is used to elevate fundamental skills and establish orientation to the capabilities of modern operational aircraft (1:4).

Ground training, in support of flight training, consists of lecture-oriented classroom subjects which are time-phased to provide the lead-in knowledge for flight application.

Ground-based simulation in current UPT consists of non-motion, nonvisual flight instrument trainers. These devices (not actually simulators) were introduced in the early 1960s. The devices are used primarily as procedures trainers. Missions flown in the trainers are prerequisites for identical instrument missions in the aircraft.

For the purpose of this report, the pilots in command of aircraft involved in major accidents were assumed to be current in that aircraft. This assumption is valid based on Air Force Regulation 51-XX which requires pilot upgrading prior to operational flights as pilot in command.

There are currently two measures of pilot proficiency in use at MAJCOM level: (1) Inspector General flight evaluations, and (2) Aircraft accidents resulting from pilot errors (pilot improficiency). The former was not considered in this research because of its subjective nature. To quantify pilot proficiency, average cost per pilot error accident was used as a direct measure of improficiency. The inverse of pilot error cost is the measure of proficiency. That is,

as pilot error cost (improficiency) increases, proficiency must decrease.

To determine trends in pilot proficiency, variances in pilot error cost were computed. Variances were categorized in two groups to ascertain the changes in pilot proficiency before and after implementation of energy conservation measures (1972).

Accidents

Air Force Regulation 127-4, Investigation and Reporting U.S. Air Force Accidents and Incidents, outlines the reporting criteria for aircraft accidents used in this research (16:A6-3).

Accidents considered in this research (Reference Tables 2-2 to 2-7) were categorized as major in that the aircraft were destroyed or received substantial damage. Destroyed is defined as damage that renders the aircraft of no further value except for possible salvage parts. It includes repairable aircraft which must be abandoned or salvaged because moving the aircraft from the mishap scene is impracticable or because the manhours or cost of repair exceeds the economical standards. Substantial damage is defined as damage in which the total direct manhours to remove, repair, and replace the damaged component(s) equals or exceeds the limit set for that particular type and model of aircraft; or damage in which a major component is destroyed/damaged beyond economic repair at any level (2:A6-3).

Accidents considered were major aircraft accidents in which the Accident Investigation Board determined pilot error (improficiency) to be the primary cause.

Major aircraft accidents were defined as those which involved pilots with more than 700 hours of total flying time. This limitation resulted in conservative dollar estimates from which to judge pilot proficiency. The assumption is that pilots with more than 700 hours should have acquired the necessary experience to perform with an optimum degree of pilot proficiency. Further, it allows for the assumption of homogeneity in pilot skills.

For accidents in which fatalities occurred, figures on accident related fatalities are based on one fatality per accident. This resulted in parity of fatality statistics between single place aircraft and multiplace aircraft.

The cost per accident was determined by the Accident Investigation Board. These costs were based on the acquisition cost of the aircraft. Cost figures used in this research are based on aircraft which were in the USAF inventory in 1970. That is, new aircraft acquired since 1970, such as the F-15, were not considered. This limitation was necessary in order to reduce the error of comparing older vintage aircraft with newer, more expensive aircraft. Additionally, all accident costs were converted to 1970 dollars. Data are not available to determine the ratio of labor cost to parts cost for

accidents in which the aircraft were not destroyed. Although converting cost to 1970 dollars allows for direct comparison, the following comparison shows that direct labor was involved in few of the 1970-1975 major aircraft accidents because the majority of the pilot error accidents resulted in total destruction of the aircraft. A comparison of the percent of aircraft destroyed and the percent repaired from 1970 through 1975 is given in Table 2-1. Figure 2-1 graphically depicts percent of aircraft destroyed, and Tables 2-2 through 2-7 depict the population of aircraft accidents from pilot errors (1970-1975).

Table 2-1

Aircraft Destroyed vs Repaired

Year	Destroyed	Repaired	Total Number of Accidents	% Repaired	% Destroyed
1970	50	15	65	23	77
1971	24	7	31	22	78
1972	32	13	45	41	59
1973	15	3	18	17	83
1974	26	7	33	21	79
1975	18	3	21	14	86

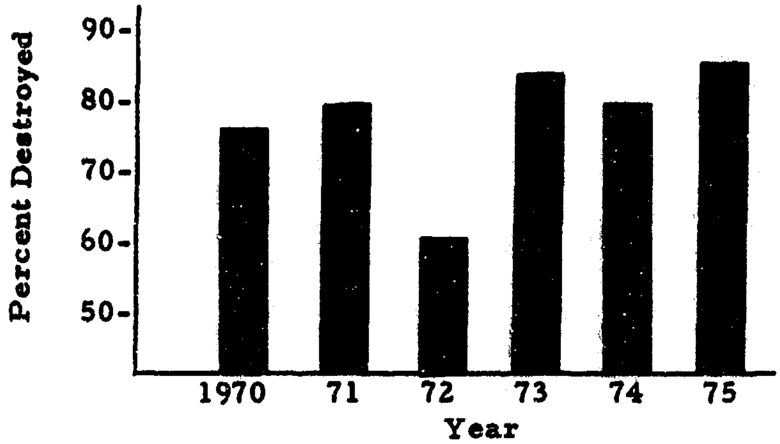

Figure 2-1

Aircraft Destroyed, Percent Attributable to Pilot Error (1970-1975)

The figures above are for major aircraft accidents; primary cause pilot error; pilots with over 700 hours; common aircraft; no battle damage.

Table 2-2

Population of Major Aircraft Accidents
Resulting from Pilot Error (1975)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
A-7	2,517,000	2777	1	0	4
A-7	2,526,468	1244	1	1	2
A-7	6,000	791	0	0	4
A-7	2,526,000	1272	1	1	2
A-7	2,517,000	2529	1	0	4
A-37	445,500	797	1	1	4
A-37	447,000	1730	1	0	5
FB-111	9,828,000	1828	1	0	5
F-4D	1,947,194	1257	1	1	3
F-4C	2,327,000	6216	1	0	3
F-104C	169,625	1399	0	0	2
F-105G	5,000	750	0	0	4
F-106A	3,699,641	1622	1	0	3
F-111E	11,877,136	2155	1	0	1
F-111F	10,970,000	1057	1	0	4
02A	91,631	2606	1	1	3
VT-29D	980,000	4940	1	1	4
T-33A	148,000	2103	1	0	4
T-33A	148,000	1416	1	0	4
T-39A	810,000	1416	1	1	3
OV-10A	461,893	1388	1	1	3

Note: Phases of Flight: 1--Low Level, 2--Air Ground Ordnance Delivery, 3--In-Flight Normal, 3--Takeoff and Climb Out, 4--Descent and Landing.

Table 2-3

Population of Major Aircraft Accidents
Resulting from Pilot Error (1974)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
A-7	2,479,000	864	1	1	1
A-7	2,526,289	1778	1	1	2
A-7	2,663,089	1095	1	0	3
B-52	8,039,000	1192	1	1	5
B-52	6,562,875	919	1	1	4
C-130	2,064,000	760	1	1	5
KC-135	3,393,000	2376	1	1	5
RF-4C	2,327,968	2319	1	0	4
RF-4C	2,575,403	749	1	1	3
F-4D	1,915,051	836	1	1	1
F-4D	1,681,592	1609	1	0	4
F-4D	28,885	1624	0	0	4
F-4E	2,488,000	1864	1	0	3
F-100F	804,444	3101	1	1	4
RF-101C	1,276,145	3266	1	1	4
F-101B	323,966	1082	0	0	4
F102A	1,173,995	2292	1	0	2
TF-104G	12,513	2103	0	0	4
F-105D	2,136,668	3731	1	0	3
F-105D	105,811	1155	0	0	2
F-106A	64,703	2839	0	0	4
F-106A	4,692,173	3103	1	1	3
F-111D	1,195,371	2096	0	0	4
F-111F	13,195,500	1355	1	1	2
HH-1H	186,199	3743	0	0	4
02A	91,631	1086	1	1	3
02A	92,188	1587	1	1	2
VT-29C	843,880	2161	1	0	4
T-38A	756,000	1916	1	1	4
T-38A	753,000	1395	1	1	2
U-1A	6,635	789	0	0	4
U-1A	121,540	3911	1	0	5
U-10A	72,725	3366	1	1	4

Note: Phases of Flight: 1--Low Level, 2--Air Ground Ordnance Delivery, 3--In-Flight Normal, 3--Takeoff and Climb Out, 4--Descent and Landing.

Table 2-4

Population of Major Aircraft Accidents Resulting from Pilot Error (1973)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
F-4D	1,976,373	2432	1	0	4
F-111E	12,337,234	2427	1	0	5
T-39A	400,000	3202	0	0	4
F-102A	1,251,209	3217	1	1	4
F-4E	2,349,592	1438	1	1	2
F-100F	44,425	4551	0	0	4
F-4D	1,681,593	1061	1	1	2
F-111A	537,715	2818	0	0	3
T-33A	147,810	2765	1	1	4
KC-135A	2,843,924	978	1	1	4
F-111D	13,688,807	3700	1	1	1
TH-1F	272,931	1317	1	0	1
F-104G	1,359,000	2559	1	1	2
F-4E	456,831	3449	0	0	2
WB-57C	1,106,930	2801	1	1	4
F-106A	3,305,435	7438	1	1	3
F-102A	1,183,995	1027	1	0	5
T-39A	212,101	3583	0	0	4
F-111A	80,635	6010	1	0	2
F-4C	1,898,365	5165	1	0	3
A-7D	2,515,335	2917	1	1	2
F-100C	9,300	1240	0	0	4
F-106A	3,353,781	1768	1	0	3
F-4E	2,430,657	2968	1	0	2
T-37B	131,292	1211	1	0	5
F-4E	2,430,657	710	1	1	2
C-130E	2,021,463	898	1	1	1
UH-1N	449,259	2602	1	1	1
HH-3E	1,065,922	3251	1	1	4
A-7D	3,045,027	1852	1	1	3
F-111D	13,688,807	1273	1	1	2

Table 2-5

Population of Major Aircraft Accidents
Resulting from Pilot Error (1972)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
A-7D	2,800,000	1896	1	0	3
T-33A	147,810	2858	1	0	3
F-111E	11,318,424	3896	1	1	1
CH-3B	766,925	1834	1	0	3
F-4C	1,898,365	1219	1	1	1
EB-66E	510,971	2924	0	0	5
C-123K	7,934	2576	0	0	4
F-101B	40,411	3121	0	0	5
UH-1N	70,000	4131	0	0	4
F-100D	515,187	3374	1	0	5
F-105D	2,136,668	2798	1	1	2
RF-4C	2,342,451	2269	1	0	3
T-33A	112,537	2467	1	1	2
F-4D	1,953,493	913	1	1	1
F-4D	1,953,493	1898	1	1	1
U-10D	21,933	2034	0	0	4
B-52D	6,580,803	1158	1	1	4
U-10D	19,720	2927	0	0	5
HH-3E	217,987	2378	0	0	5
02A	79,699	1950	1	0	4
C-124C	1,646,406	2266	1	1	4
F-4D	1,681,593	1695	1	1	1
B-52G	8,910,769	1732	1	0	4
F-4E	2,352,306	2635	1	1	2
F-4E	76,880	1903	0	0	4
C-130E	164,753	1180	0	0	4
U-2C	2,450,000	1862	0	0	5
F-111F	12,368,293	1978	1	0	3
RF-4C	2,278,682	4405	1	0	4
WB-57F	9,019,780	6162	1	1	4
A-37B	439,868	6035	1	0	5
B-52	7,692,613	977	1	0	5
T-38A	757,833	1209	1	0	3
T-39A	479,700	3461	0	0	4
B-52	7,692,613	1618	1	1	3

Table 2-5 (continued)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
A-37A	351,441	3359	1	0	5
KC-135A	145,000	1365	0	0	3
F-4E	2,349,592	1276	0	1	2
C-130A	19,700	2621	0	0	4
F-4D	1,942,512	912	1	1	5
F-4E	125,371	1426	0	0	4
QU-22B	375,000	816	1	0	5
C-124C	1,646,406	5531	1	0	4
F-106A	275,279	1858	0	0	5
T-38A	757,833	4274	1	1	5
F-4D	1,681,593	1578	1	0	3
F-4E	2,640,143	1842	1	0	4
A-37B	440,437	1547	1	0	3
FB-111A	744,722	2388	0	0	4
A-37B	439,868	839	1	1	1
YF-4E	1,898,365	4770	1	1	3
HH-34J	380,000	2052	1	0	3
F-4D	1,928,465	1193	1	0	4
F-4D	1,531,959	2063	1	0	4
F-4D	1,935,339	828	1	1	3
RF-4C	2,340,691	2158	1	1	3
F-104G	1,359,000	2228	1	1	2
RF-4C	145,350	3361	0	0	4
F-102A	1,032,594	1088	1	1	3
F-101B	7,732	1695	0	0	4
F-101B	1,754,066	1251	1	1	4
F-4E	2,349,592	2196	1	1	3

Table 2-6

Population of Major Aircraft Accidents
Resulting from Pilot Error (1971)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
F-101B	1,545,649	4182	1	0	2
C-7A	960,000	1241	1	0	5
F-100C	663,181	1050	1	1	1
F-105B	5,649,543	1411	1	1	2
F-4C	1,898,365	950	1	1	5
F-5C	1,898,365	1210	1	0	5
F-4E	20,386	2735	0	0	3
C-47D	95,466	4543	1	1	3
F-4D	1,681,593	743	1	1	4
UH-1F	22,166	1069	0	0	5
F-100D	696,989	2261	1	1	4
F-4D	1,870,262	1960	1	1	4
F-102A	1,183,995	2434	1	0	2
OV-10A	506,369	1789	1	1	3
F-111E	10,932,643	4164	1	1	3
VC-47A	95,466	5393	1	1	4
F-4D	1,700,000	4604	1	0	3
HH-43	112,303	2333	0	0	1
0-2A	92,188	1506	1	1	1
A-7D	3,252,371	4301	1	1	2
QU-22B	27,979	1095	0	0	4
A-7D	3,252,371	1734	1	0	4
F-101B	1,496,380	2254	1	1	5
U-10D	12,719	1245	0	0	4
A-1H	296,960	4190	1	0	4
CH-3E	268,341	2633	0	0	5
0-2A	92,188	1558	1	0	4
RF-101H	2,979,745	948	1	1	5
F-4E	2,401,068	1208	1	1	3
F-4E	2,459,142	1537	1	0	4
B-57E	1,027,100	4064	1	1	4
F-4D	305,649	1238	0	0	5
F-106A	3,305,435	3078	1	0	3
EC-47Q	7,864	1066	0	0	5
CH-53C	2,292,500	1916	1	0	4
C-130E	1,940,400	1697	1	1	5

Table 2-6 (continued)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
F-101A	10,900	6025	0	0	5
U-2A	2,450,000	1740	1	1	5
F-111A	1,946,989	3113	0	0	4
F-102A	1,183,995	4500	1	0	3

Table 2-7

Population of Major Aircraft Accidents
Resulting from Pilot Error (1970)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
RF-4C	2,332,210	7140	1	0	5
F-101B	1,754,066	1081	1	0	4
F-4C	1,898,365	2124	1	0	3
F-84F	769,330	5073	1	1	2
T-33A	147,810	2030	1	0	5
C-130E	36,747	2156	0	0	5
F-4E	2,459,142	4374	1	0	2
F-100F	804,444	1282	1	0	5
F-105G	392,982	3466	0	0	4
F-4D	260,650	704	0	0	4
RF-84F	667,608	2296	1	0	4
C-124C	1,822,214	4695	1	1	3
HH-43B	299,009	5115	0	0	1
F-84F	769,330	2537	1	0	5
F-102A	1,183,993	2028	1	0	4
0-2A	4,000	1401	1	0	3
C-130E	1,981,409	4230	1	1	3
FB-111A	11,278,828	5115	1	1	4
C-123K	22,934	1394	0	0	4
F-4D	1,681,593	2091	1	1	4
F-4E	235,659	4688	0	0	4
CH-3E	792,722	732	1	1	5
EB-66C	3,066,501	2815	1	0	4
HH-43B	304,000	1924	1	1	3
T-33A	147,810	3123	1	1	1
RF-4C	2,334,844	3564	0	0	3
F-4D	1,681,593	735	1	1	2
RF-101A	1,604,963	2356	1	1	1
H-3E	171,557	8641	0	0	1
A-7D	3,250,000	1801	1	1	5
UH-1F	272,931	1420	1	0	4
C-7A	19,522	2036	0	0	4
F-105B	365,699	2275	0	0	4
F-4E	2,399,758	771	1	1	2

Table 2-7 (continued)

Type A/C	Cost	Total IP/FP Time	Destroyed	Fatality	Phase of Flight
T-38A	764,868	2398	1	0	4
OV-10A	506,365	1393	1	1	5

Simulators

1972 marked the implementation of increased use of flight simulators as a substitute for actual flight. Ground-based simulators are generally less expensive, easier to handle and to maintain, and independent of weather (3:3). Examples of various types of simulators are equipment simulators (e.g., the F-111 simulator and other piloted simulators in which a human operator performs a control task); environment simulators (e.g., the lunar surface simulator); situation simulators (e.g., simulation of turbulence, attack, approach, or landing); condition simulators (e.g., instrument flight conditions, visual flight conditions, night or daylight, zero-G); and procedures or mission simulators (e.g., for combat, space flight, supersonic transport profile) (4:5).

Simulators have been categorized as "part-task" and "whole-task" simulators. A part-task simulator is defined as a device which represents only specific characteristics or functions of the task, such as radar observation, navigation, or fire control. An illustration of a part-task simulation is the pilot's job to position a target in the center of a radar scope. In contrast, the whole-task simulation has been defined as the "deliberate effort to achieve complete representation of equipment characteristics and in-flight mission factors [3:1]." The latter include the environmental factors which are thought to be important. Examples of whole-task simulators are the space

flight simulators which were used by the astronauts for the simulation of the Mercury, Gemini, and Apollo missions.

Another grouping of simulators is by fixed-base or stationary and moving-base or dynamic simulators. The first group consists mostly of cockpits of aircraft or facilities, in which a pilot or an aircrew can become familiar with the flight instruments, their arrangement, and certain operating procedures in the absence of dynamic and motion cues. These cues are available in the moving-base simulator. In order to obtain dynamic responses of the pilot or the vehicle, cockpits of aircraft and entire space capsules have been placed on wheels, gimbals, pulleys, or air bearings (3:2).

The driving force behind use of simulators as a substitute for actual flight is the theory of learning transfer. Learning transfer is a concept which derives both from learning theory and from practice. In both instances it has been shown that skills acquired in a particular situation can be successfully transferred to a similar situation. This principle has long been applied to flying training. Although Link Trainers, which were the first simulators used to this end, were rather crude devices for instrument flight training, they proved useful for practicing navigation owing to the positive transfer of learned behavior patterns from one situation to the other. If the learned functions disturb each other, negative transfer occurs. On the basis of present evidence it appears that flight simulators

generally are very useful, but that the amount of transfer of skill from the simulator to the aircraft depends upon a variety of factors which are still the subject of experimental investigation (3:3).

This research does not address individual differences in simulators, but assumes homogeneity in simulator training capability. That is, each simulator supporting a weapon system is adequately training the pilot for his flight environment. An examination was made of differences in simulator time per command (Table 2-8) for the research period (1970-1975). A similar examination was made of actual flight time per year for that period. Simulator and flight time per year were then compared to determine the flight/simulator ratios (Tables 2-9 through 2-11). The ratios were compared with pilot error costs for the corresponding periods. Using multiple regression, a general model was developed to predict expected cost of pilot errors (improficiency) based on simulation and flight variables.

Table 2-8 provides a summary of simulator hours for the years 1970-1975. Tables 2-9 through 2-11 provide summaries of simulator/flight ratios for the same period. The simulator hour breakout per command was only available for 1974 and 1975. All other years represent total time throughout the Air Force.

Table 2-8

Simulator Hours (1970-1975)

Command	1975	1974	1973	1972	1971	1970
Air National Guard (ANG)	18,431	24,846				
Air Force Reserve (AFR)	7,883	7,616				
Air Training Command (ATC)	312,019	242,194				
Air Defense Command (ADC)	10,876	8,334				
Air Forces in Europe (AFE)	23,815	20,471				
Military Airlift Command (MAC)	154,518	72,006				
Strategic Air Command (SAC)	159,154	85,088				
Pacific Air Forces (PAF)	9,257	9,389				
Tactical Air Command (TAC)	85,865	125,950				
AF Logistics Command (AFLC)	3,536	8,663				
AF Systems Command (AFSC)	1,190	2,177				
*Miscellaneous Total	6,606	2,119				
Total	793,150	608,853	424,556	382,101	300,101	290,000

*Miscellaneous includes all users of simulators whose average yearly utilization rate is less than 1,000 hours. Figures were provided by Headquarters Air Force Logistics Command.

Table 2-9

1975 Ratio SIM/Flight Hours

Command	SIM	Flight	Ratio
ADC	10,876	105,145	.10344
AFE	23,815	164,169	.19989
AFR	7,883	131,716	.05985
ANG	18,431	386,767	.04765
ATC	312,019	651,977	.47857
LOG	3,536	13,649	.25907
MAC	154,518	665,382	.23222
PAF	9,257	234,359	.03959
SAC	159,154	387,581	.41063
SYS	1,190	52,249	.02278
TAC	85,865	395,364	.21718
*Misc. Total	6,605	44,591	.14815
Total	793,150	3,180,038	.24942

*Miscellaneous includes all users of simulators whose average yearly utilization rate is less than 1,000 hours. Figures were provided by Headquarters Air Force Logistics Command.

Table 2-10

1975 Ratio SIM/Flight Hours

Command	SIM	Flight	Ratio
ADC	8,334	136,484	.06106
AFE	20,471	191,409	.10695
AFR	7,616	138,745	.05489
ANG	24,847	416,399	.05967
ATC	242,194	800,699	.30248
LOG	8,663	35,221	.24596
MAC	72,006	506,346	.14221
PAF	9,389	372,221	.02522
SAC	85,088	507,964	.16751
SYS	2,177	70,742	.03077
TAC	125,950	601,587	.20936
*Misc. Total	2,119	96,926	.02186
Total	608,853	3,171,262	.19199

*Miscellaneous includes all users of simulators whose average yearly utilization rate is less than 1,000 hours. Figures were provided by Headquarters Air Force Logistics Command.

Table 2-11

1970-1973 Ratio SIM/Flight Hours

Year	SIM	Flight	Ratio
1970	290,000	5,697,017	.0509
1971	300,101	4,888,559	.06139
1972	382,101	3,853,228	.09916
1973	424,556	3,539,023	.11996

CHAPTER III

TESTS OF HYPOTHESES

The tests of hypotheses were made without employing inferential statistics. This was possible because a census of pilot error accidents, flight simulator usage, and flying hours was analyzed. The analyses consisted of making direct comparisons of aircraft accident data, total flying hours, and flight simulator data for the years 1970 through 1975. This time frame was divided into two periods, Period I (1970-1972), representing the period before Energy Conservation Measures (ECM) implementation, and Period II (1973-1975), representing the period after ECM implementation.

The basic objective was to determine if the level of pilot proficiency has decreased since ECM implementation. Pilot proficiency is defined as the average cost per accident per given time period. This cost, along with the associated flight hours, simulator hours, fatality count, and percent of aircraft destroyed were used to compare pilot proficiency before and after ECM implementation. In other words, the average deflated cost of accidents resulting from pilot errors is a measure of pilot proficiency. A decrease in proficiency is reflected in the seriousness of pilot errors, which, in turn,

is reflected by increased costs of pilot error accidents. In addition to increased cost (resulting from decreased proficiency), it also follows that the percent of fatalities and percent of aircraft destroyed should increase with a decrease in pilot proficiency. These factors were examined and compared for the two periods to ascertain the affects of increased simulation and reduced flying time on pilot proficiency.

RESEARCH HYPOTHESES

(I) There has been a decrease in total pilot flying proficiency since 1972 (implementation of energy conservation measures).

(II) The decrease in flying proficiency can be attributed to reductions in actual flight hours and to increases in the use of flight simulators as a substitute for actual flight in maintaining flying proficiency.

ASSUMPTIONS

(a) The time period from which the historical data are selected (January 1970 through December 1975) is of sufficient length to yield valid data pertaining to the objective of this study.

(b) Pilots with more than 700 hours total flying time should possess the skills necessary to perform at optimum proficiency levels.

c. The current simulators are being utilized for maximum training effectiveness and homogeneity exists in simulator training capability.

d. All pilots were current as aircraft commanders and/or instructor pilots, in accordance with Air Force Regulation 51-XX.

e. Homogeneity exists in basic skills acquired by the pilot population.

LIMITATIONS

a. This research considered only those aircraft common to all years of the historical period. The newer series of aircraft (e.g., F-15, C-5A) were not considered.

b. The conclusions derived from this research apply only to Air Force pilots with more than 700 hours total aircraft commander time and/or instructor pilot time, involved in major aircraft accidents. Predictions are only valid for the range of data collected. Predictions of characteristics concerning different populations are based upon logical inferences only.

<u>Results of Analysis</u>

A statistical summary of pilot error accident data is presented in Table 3-1. The pilot error accident costs were adjusted to 1970 dollars to provide parity in comparing cost figures. The fatality

figures in Table 3-1 represent one fatality for each accident in which a fatality or fatalities occurred. This was done to provide parity when comparing multiplace aircraft with single place aircraft.

Figure 3-1 graphically displays the total cost of accidents for 1970 through 1975. All cost figures are adjusted to 1970 dollars.

Figure 3-2 graphically displays the average cost of accidents for the period 1970 through 1975.

In order to compare pre-ECM and post-ECM pilot proficiency, 1970 through 1972 was designated Period I (pre-ECM) and 1973 through 1975 was designated Period II (post-ECM). Accident statistics for Periods I and II are presented in Table 3-2. The total cost of pilot error accidents for Period I was $209,702,491, while the total cost of accidents for Period II was $140,558,264. Although this represents a reduction in pilot error cost of $69,144,227, the average cost per accident increased from $1,505,976 for Period I, to $1,978,786 in Period II, (Reference Table 3-2). This represents an increase in the severity of pilot errors by $472,810 for each occurrence.

Graphical representations of pilot errors resulting in fatalities are presented in Figures 3-4 and 3-5. In Period I, pilot errors resulted in 40 fatalities while in Period II pilot errors resulted in 33 fatalities (Reference Table 3-2). While this represents a decrease in total fatalities from Period I to Period II, the average fatality per accident increased from .28 to .46. That is, the increased severity

Table 3-1

Statistical Data Summary (1970 thru 1975)
Air Force Aircraft Accidents

Year	Total Accident Cost	Deflator*	Adjusted Total Accident Cost	Total Number of Accidents	Total Fatalities
1970	$79,650,309	0	$79,650,309	65	18
1971	41,229,693	2.7	40,116,491	31	12
1972	92,999,680	3.3	89,930,691	45	10
1973	36,323,845	6.2	34,071,767	18	9
1974	66,659,359	11.0	59,326,830	33	16
1975	51,937,959	9.2	47,159,667	21	8

Year	Average Cost/Accident	Fatalities/Accident
1970	$1,225,389	.28
1971	1,294,080	.39
1972	1,998,460	.22
1973	1,892,876	.50
1974	1,797,783	.48
1975	2,245,698	.38

Figures are for major aircraft accidents; primary cause pilot error; pilots with over 700 hours; common aircraft; no battle damage.

*Deflator is used to adjust each year's dollar value to 1970 base year.

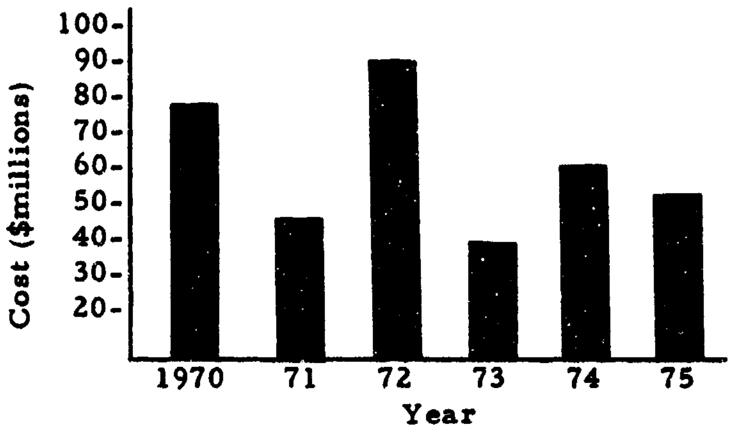

Figure 3-1

Total Accident Cost/Year (1970-1975)

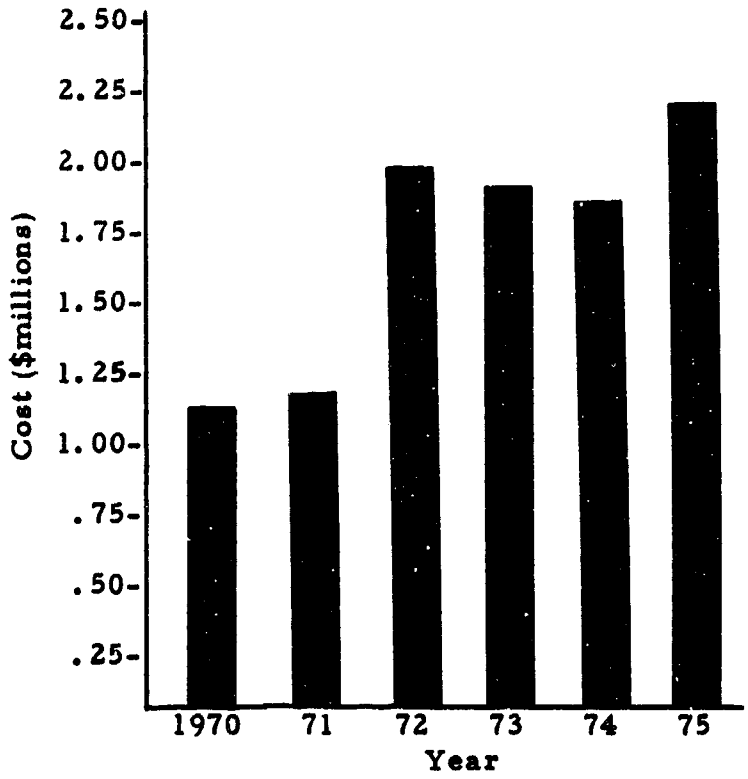

Figure 3-2

Average Cost/Accident (1970-1975)

Table 3-2

Statistical Data Comparison
Period I (1970-72) vs Period II (1973-75)
Air Force Aircraft Accidents

Period	Total Accident Cost	Total Number of Accidents	Total Fatalities
I	$209,702,491	141	40
II	140,558,264	72	33

Period	Average Cost/ Accident	Average Fatalities/ Accident
I	$1,505,976	.28
II	1,978,786	.46

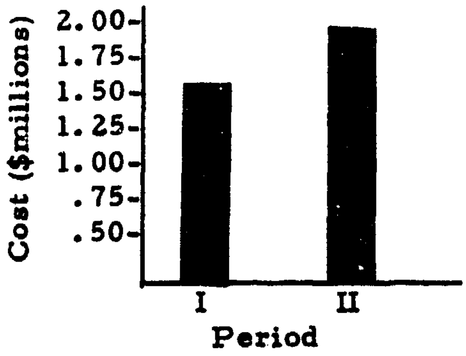

Figure 3-3

Average Cost/Accident

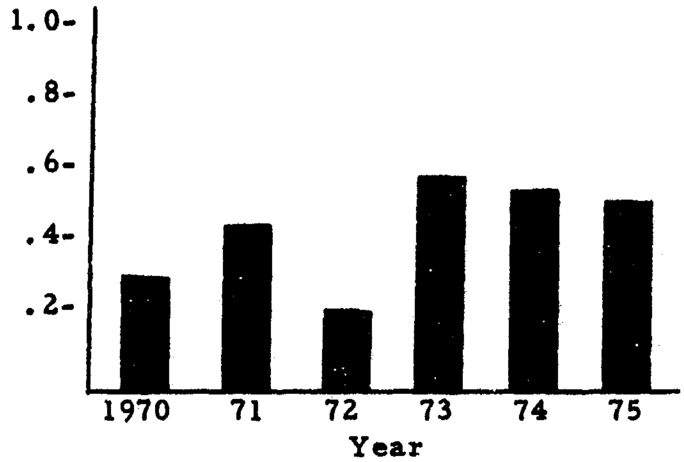

Figure 3-4

Fatalities/Accident: Percentage
Comparison (1970-1975)

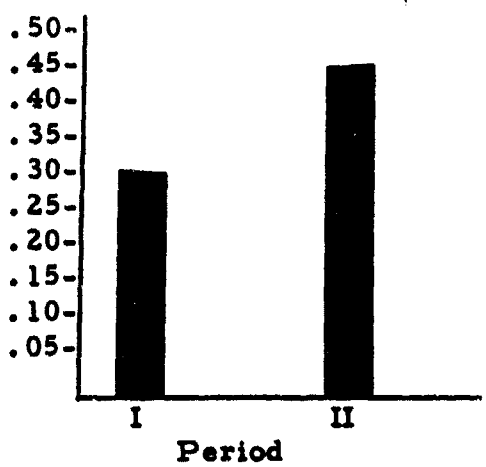

Figure 3-5

Fatalities/Accident

of pilot error resulted in a 64% increase in average fatalities per accident in Period II.

Pilot improficiency was also analyzed in terms of aircraft destroyed. The assertion is that the seriousness of a pilot error can be judged by the extent of damage done to an aircraft. In Period I, 75.18% of all pilot errors resulted in destruction of the aircraft beyond economical repair, while in Period II, 81.94% of pilot errors resulted in total aircraft destruction (Reference Table 3-3). This represents an 8.99% increase in the number of aircraft destroyed from Period I to Period II.

The decrease in total cost, total number of fatalities, and total number of aircraft destroyed follows the total reduction in flying time from Period I to Period II (Reference Tables 3-4 and 3-5). In Period I, total flying time for the Air Force was 14,438,804 hours while in Period II it was 9,890,323. This represents a 31.5% reduction in flying time from Period I to Period II. Concurrently, the simulator time was increased from 972,202 hours to 1,826,559 hours (Reference Figures 3-6 and 3-7). This 87.8% increase in simulator hours purportedly would compensate for the reduction in flying hours, and maintain the same level of pilot proficiency.

Table 3-3

Aircraft Destroyed vs Aircraft Repaired

Period	Destroyed	Repaired	Total Number of Accidents	Percent Destroyed
I	106	35	141	75.18%
II	59	13	72	81.94%

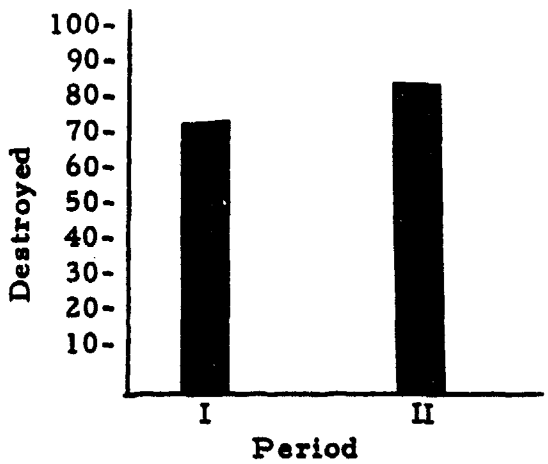

Figure 3-6

Percent Aircraft Destroyed

Table 3-4

Yearly Comparison of Flight/SIM Hours

Year	Adjusted Average Cost/Accident	Flight Hours	SIM Hours	Flight/ SIM Ratio
1970	$1,225,389	5,697,017	290,000	19.6:1
1971	1,294,080	4,888,559	300,101	16.3:1
1972	1,998,460	3,853,228	382,101	10.1:1
1973	1,892,876	3,539,023	424,556	8.3:1
1974	1,797,783	3,171,262	608,853	5.2:1
1975	2,245,698	3,180,038	793,150	4.0:1

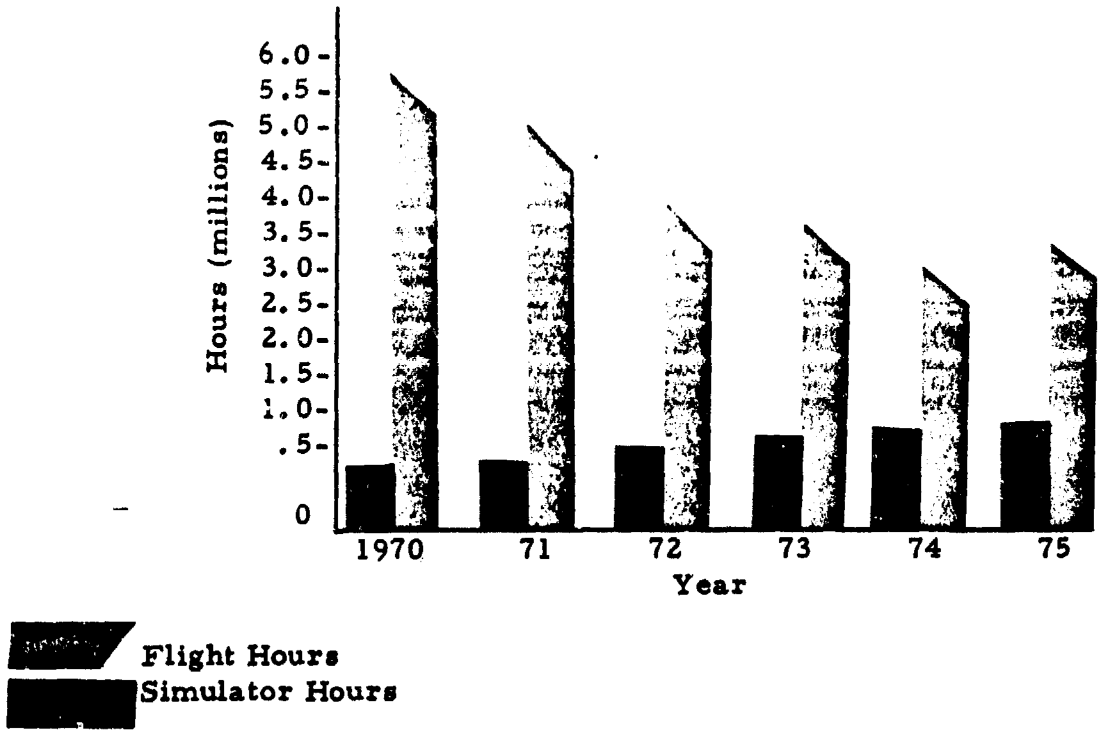

Figure 3-7

Yearly Flight/SIM Hours

Table 3-5

Period I and II Comparison of Flight/SIM Hours

Period	Average Cost/ Accident	Total Flight Hours	Total SIM Hours	Flt/SIM Ratio
I	$1,505,976	14,438,804	972,202	14.9:1
II	1,978,786	9,890,323	1,826,559	5.4:1

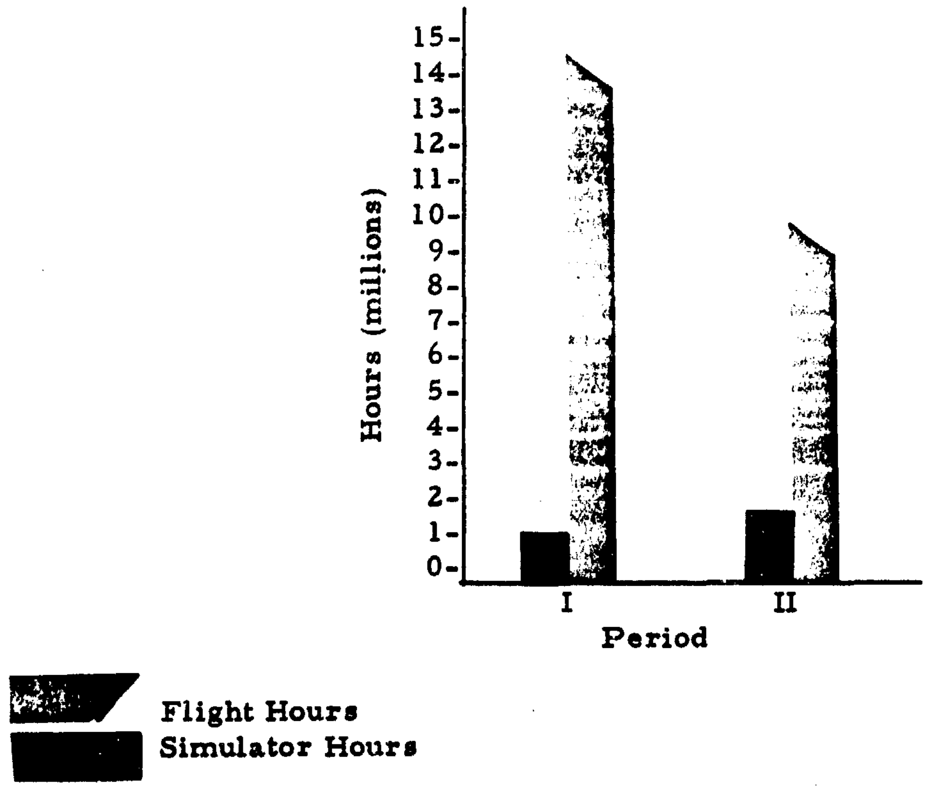

Figure 3-8

Period Flight/SIM Hours

CHAPTER IV

FURTHER ACCIDENT ANALYSIS

This chapter provides a more detailed analysis of pilot error accidents by considering the affect of the variables, total instructor pilot time, simulator/flight ratio, phase of flight, cost of accident, and type of aircraft. Data for the years 1974 and 1975 were analyzed in order to determine current trends in pilot errors since the implementation of energy conservation measures which marked the greater use of simulation as a substitute for actual flight (Reference Tables 2-2, 2-3, 2-9 and 2-10). The Statistical Package for the Social Sciences (SPSS) provided the computerized data analysis. All possible combinations of variables were analyzed for significance. The most significant tests will be presented.

The first series of tests were performed using the SPSS codebook program. Table 4-1 gives an analysis of the 30 types of aircraft involved in pilot error accidents in 1974 and 1975. Table 4-2 is an analysis of the cost of the 56 major aircraft accidents resulting from pilot error in 1974 and 1975.

Table 4-3 gives an analysis of 1974 and 1975 accidents according to simulator/flight ratio of the parent command.

Table 4-1

Analysis of Accidents by Aircraft Type

Type A/C	Value	Absolute Frequency	Relative Frequency (Percent)	Adjusted Frequency (Percent)	Cumulative Adj Freq (Percent)
A7	1	8	14.3	14.3	14.3
A37	2	2	3.6	3.6	17.9
B52	3	2	3.6	3.6	21.4
C130	4	1	1.8	1.8	23.2
F100F	5	1	1.8	1.8	25.0
F101B	6	1	1.8	1.8	26.8
F102A	7	1	1.8	1.8	28.6
F104C	8	1	1.8	1.8	30.4
F104G	9	1	1.8	1.8	32.1
F105D	10	2	3.6	3.6	35.7
F105G	11	1	1.8	1.8	37.5
F106A	12	3	5.4	5.4	42.9
F111D	13	1	1.8	1.8	44.6
F111F	14	3	5.4	5.4	50.0
F4C	15	2	3.6	3.6	53.6
F4D	16	5	8.9	8.9	62.5
F4E	17	1	1.8	1.8	64.3
FB111	18	1	1.8	1.8	66.1
HH1H	19	1	1.8	1.8	67.9
KC135	20	1	1.8	1.8	69.6
02A	21	3	5.4	5.4	75.0
OV10A	22	1	1.8	1.8	76.8
RF101C	23	1	1.8	1.8	78.6
RF4C	24	2	3.6	3.6	82.1
T33A	25	2	3.6	3.6	85.7
T38A	26	2	3.6	3.6	89.3
T39A	27	1	1.8	1.8	91.1
U100	28	3	5.4	5.4	96.4
VT29C	29	1	1.8	1.8	98.2
VT29D	30	1	1.8	1.8	100.0
Total		56	100.0	100.0	100.0

Table 4-1 (continued)

Aircraft Type Summary Statistics

Mean	14.125	Std Error	1.230
Mode	1.000	Std Dev	9.203
Kurtosis	-1.206	Skewness	0.005
Minimum	1.000	Maximum	30.000
Median	14.500		
Variance	84.693		
Range	29.000		
Valid Observations	56		
Missing Observations	0		

Table 4-2

Analysis of Aircraft Accidents by Cost

Cost	Absolute Frequency	Relative Frequency (Percent)	Adjusted Frequency (Percent)	Cumulative Adj Freq (Percent)
5,000	1	1.8	1.8	1.8
6,000	1	1.8	1.8	3.6
6,635	1	1.8	1.8	5.4
12,513	1	1.8	1.8	7.1
28,885	1	1.8	1.8	8.9
64,703	1	1.8	1.8	10.7
72,725	1	1.8	1.8	12.5
91,631	2	3.6	3.6	16.1
92,188	1	1.8	1.8	17.9
105,811	1	1.8	1.8	19.6
117,399	1	1.8	1.8	21.4
121,540	1	1.8	1.8	23.2
148,000	2	3.6	3.6	26.8
169,625	1	1.8	1.8	28.6
186,199	1	1.8	1.8	30.4
323,966	1	1.8	1.8	32.1
445,000	1	1.8	1.8	33.9
447,000	1	1.8	1.8	35.7
461,893	1	1.8	1.8	37.5
753,000	1	1.8	1.8	39.3
756,000	1	1.8	1.8	41.1
804,444	1	1.8	1.8	42.9
810,000	1	1.8	1.8	44.6
843,880	1	1.8	1.8	46.4
980,000	1	1.8	1.8	48.2
1,195,371	1	1.8	1.8	50.0
1,276,145	1	1.8	1.8	51.8
1,681,592	1	1.8	1.8	53.6
1,915,051	1	1.8	1.8	55.4
1,947,194	2	3.6	3.6	58.9
2,064,000	1	1.8	1.8	60.7
2,136,668	1	1.8	1.8	62.5
2,327,000	2	3.6	3.6	66.1
2,327,968	1	1.8	1.8	67.9
2,479,000	1	1.8	1.8	69.6
2,488,000	1	1.8	1.8	71.4

Table 4-2 (continued)

Cost	Absolute Frequency	Relative Frequency (Percent)	Adjusted Frequency (Percent)	Cumulative Adj Freq (Percent)
2,517,000	2	3.6	3.6	75.0
2,526,000	1	1.8	1.8	76.8
2,526,289	1	1.8	1.8	78.6
2,526,468	1	1.8	1.8	80.4
2,575,403	1	1.8	1.8	82.1
2,663,089	1	1.8	1.8	83.9
3,393,000	1	1.8	1.8	85.7
3,699,641	1	1.8	1.8	87.5
4,692,173	1	1.8	1.8	89.3
6,562,875	1	1.8	1.8	91.1
8,039,000	1	1.8	1.8	92.9
9,829,000	1	1.8	1.8	94.6
10,970,000	1	1.8	1.8	96.4
11,877,136	1	1.8	1.8	98.7
13,195,500	1	1.8	1.8	100.0
Total	56	100.0	100.0	100.0

Accident Cost Summary Statistics

Mean	219900.438	Std Error	409373.176
Mode	947194.000	Std Dev	063468.344
Kurtosis	4.228	Skewness	2.186
Minimum	5000.000	Maximum	195500.000

Median	235758.000
Variance	0.938E 13
Range	190500.000

Valid Observations	56
Missing Observations	0

Table 4-3

Accident Analysis Based on Simulator/
Flight Ratio of Parent Command

SIM/Flt Ratio	Absolute Frequency	Relative Frequency (Percent)	Adjusted Frequency (Percent)	Cumulative Adj Freq (Percent)
0.039590	1	1.8	1.8	1.8
0.047650	3	5.4	5.4	7.1
0.059600	3	5.4	5.4	12.5
0.059670	7	12.5	12.5	25.0
0.061060	5	8.9	8.9	33.9
0.103440	5	8.9	8.9	42.9
0.167510	3	5.4	5.4	48.2
0.209360	14	25.0	25.0	73.2
0.217180	11	19.6	19.6	92.9
0.302480	3	5.4	5.4	98.2
0.478570	1	1.8	1.8	100.0
Total	56	100.0	100.0	100.0

Simulator/Flight Ratio Summary
Statistics

Mean	0.157	Std Error	0.012
Mode	0.209	Std Dev	0.090
Kurtosis	0.932	Skewness	0.657
Medium	0.040	Maximum	0.479
Median	0.190		
Variance	0.008		
Range	0.439		

Table 4-4 provides an analysis of 1974 and 1975 accidents according to phase of flight. The following codes are used to denote phases of flight:

Phase 1	Low Level
Phase 2	Air to Ground Ordnance Delivery
Phase 3	In-Flight Normal
Phase 4	Descent and Landing
Phase 5	Takeoff and Climb Out

Table 4-5 analyzes the accident data according to instructor pilot/first pilot (IP/FP) time of the pilot in command of the aircraft.

Table 4-4

Accident Analysis by Phase of Flight

Phase of Flight		Absolute Frequency	Relative Frequency (Percent)	Adjusted Freq (Percent)	Cumulative Adj Freq (Percent)
Low Level	1	3	5.4	5.4	5.4
Air to Ground Ordnance Delivery	2	9	16.1	16.1	21.4
In-Flight Normal	3	14	25.0	25.0	46.4
Descent & Landing	4	24	42.9	42.9	89.3
Takeoff and Climb Out	5	6	10.7	10.7	100.0
Total		56	100.0	100.0	100.0

Note: Table 4-4 developed using SPSS codebook computer program. Figures represent 1974 and 1975 major aircraft accidents with pilot error as primary cause.

Table 4-5

Accident Analysis Based on Instructor Pilot/ First Pilot Time of Pilot in Command

IP/FP Time	Absolute Frequency	Relative Frequency (Percent)	Adjusted Frequency (Percent)	Cumulative Adj Freq (Percent)
749	1	1.8	1.8	1.8
750	1	1.8	1.8	3.6
760	1	1.8	1.8	5.4
789	1	1.8	1.8	7.1
791	1	1.8	1.8	8.9
797	1	1.8	1.8	10.7
836	1	1.8	1.8	12.5
864	1	1.8	1.8	14.3
919	1	1.8	1.8	16.1
1057	1	1.8	1.8	17.9
1082	1	1.8	1.8	19.6
1086	1	1.8	1.8	21.4
1095	1	1.8	1.8	23.2
1155	1	1.8	1.8	25.0
1192	1	1.8	1.8	26.8
1244	1	1.8	1.8	28.6
1257	2	3.6	3.6	32.1
1272	1	1.8	1.8	33.9
1355	1	1.8	1.8	35.7
1388	1	1.8	1.8	37.5
1395	1	1.8	1.8	39.3
1399	1	1.8	1.8	41.1
1416	2	3.6	3.6	44.6
1587	1	1.8	1.8	46.4
1609	1	1.8	1.8	48.2
1622	1	1.8	1.8	50.0
1624	1	1.8	1.8	51.8
1730	1	1.8	1.8	53.6
1778	1	1.8	1.8	55.4
1828	1	1.8	1.8	57.1
1864	1	1.8	1.8	58.9
1916	1	1.8	1.8	60.7
2096	1	1.8	1.8	62.5
2103	2	3.6	3.6	66.1
2155	1	1.8	1.8	67.9
2161	1	1.8	1.8	69.6

Using SPSS crosstabs computer program, the accident variables were analyzed for interrelationships. A crosstabulation of cost of accident by aircraft type is shown below:

Chi Square = 1624.00047 Significance = 0.0008

Contingency Coefficient = .98319

The Chi Square test of independence indicates that both cost and aircraft type are dependent at a confidence level of 99.99%.

The measure of the extent of association or relation between cost and aircraft type has a contingency coefficient of .98319. A crosstabulation of simulator/flight ratio by aircraft type is shown below:

Chi Square = 497.34236 Significance = 0.000

Contingency Coefficient = .94805

The variability of simulator/flight ratio and aircraft type follow a Chi Square distribution with a dependency relationship with 100% confidence.

Simulator/flight is highly contingent on the type of aircraft. A crosstabulation of IP/FP time by aircraft type is given below:

Chi Square = 1540.00041 Significance = 0.1315

Contingency Coefficient = 0.98230

Chi Square test of independence between IP/FP time and aircraft type shows a relationship significant, with 86.85% confidence.

Type of aircraft is 98.2% contingent on IP/FP time. A crosstabulation of the five phases of flight by aircraft type is given below:

Chi Square = 104.40648 Significance = 0.2271

Contingency Coefficient = 0.806778

Chi Square test of independence between phase of flight and aircraft type shows a dependency relationship at the 87.29% confidence level.

Phase of flight is 80.68% contingent on aircraft type.

ANALYSIS OF VARIANCE

Using SPSS ANOVA computer program, an analysis was made on accident variables.

Test number 1 (Reference Table 4-6) analyzed the variance in cost of accident by aircraft type. The results are given below.

ANOVA Table

	Sum of Squares	Degrees of Freedom	Mean Square
Between groups	0.4902	29	0.1690
Within groups	0.2596	26	0.9983
Total	0.5162	55	

Table 4-6

Cost of Accidents by Aircraft Types

Code	Value Label	Sum	Mean	Std Dev	Sum of Sq	N
1	A7	760846.000	220105.750	896261.664	0.562E 13	8
2	A37	892000.000	446000.000	1415.073	002432.000	2
3	B52	601875.000	300937.500	043777.945	0.109E 13	2
4	C130	064000.000	064000.000	0	0	1
5	F100F	804444.000	804444.000	0	0	1
6	F101B	323966.000	323966.000	0	0	1
7	F102A	117399.000	117399.000	0	0	1
8	F104C	169625.000	169625.000	0	0	1
9	F104G	12513.000	12513.000	0	0	1
10	F105D	242479.000	121239.500	436032.766	0.206E 13	2
11	F105G	5000.000	5000.000	0	0	1
12	F106A	456517.000	818839.000	436232.531	0.119E 14	3
13	F111D	195371.000	195371.000	0	0	1
14	F111F	042636.000	014212.000	119064.969	0.250E 13	3
15	F4C	654000.000	327000.000	0	52224.000	2
16	F4D	519916.000	503983.203	832061.898	0.277E 13	5
17	F4E	488000.000	488000.000	0	0	1
18	FB111	828000.000	828000.000	0	0	1
19	HH1H	186199.000	186199.000	0	0	1
20	KC135	393000.000	393000.000	0	0	1
21	02A	275450.000	91816.667	321.720	207007.000	3

Table 4-6 (continued)

Code	Value Label	Sum	Mean	Std Dev	Sum of Sq	N
22	OV10A	461893.000	461893.000	0	0	1
23	RF101C	276145.000	276145.000	0	0	1
24	RF4C	903371.000	451685.500	174963.117	092416.000	2
25	T33A	296000.000	148000.000	0	0	2
26	T38A	509000.000	754500.000	2121.433	500480.000	2
27	T39A	810000.000	810000.000	0	0	1
28	U100	200900.000	66966.667	57668.524	317248.000	3
29	VT29C	843880.000	843880.000	0	0	1
30	VT29D	980000.000	980000.000	0	0	1
Total		124314425.000	2219900.438	3063468.438	0.260E 14	56

$F_s = 16.9322$

$\alpha = .001$ 99.9% confidence

$F_c = 3.44$

There is a significant difference in at least one pair of means. Further analysis using Scheffe's interval (Wonnacott, Introductory Statistics, 1972) provide the following.

H_0: $u_1 - u_2 = 0$

H_1: $u_1 - u_2 \neq 0$

$$(\overline{X}_1 - \overline{X}_2) \pm \sqrt{F_{.001 \; r(n-1)}^{\;n-1}} * \sqrt{S_p^2} * \sqrt{\frac{r-1}{n} 2}$$

$$\pm \sqrt{3.44} * \sqrt{.9983} * \sqrt{\frac{29}{56} 2}$$

$$\pm 1.9193$$

Note: H_0, can be rejected for all differences in mean (Reference Table 4-6, mean).

The differences in mean cost of accidents are statistically significant in that none of the differences in means enclose the value of zero. This statement is true with 99.9% confidence.

A second ANOVA analyzed simulator/flight ratio by type of aircraft (Reference Table 4-7). Results are shown below.

ANOVA Table

	Sum of Squares	Degrees of Freedom	Mean Square
Between groups	0.4475	29	0.0154
Within groups	0.0027	26	0.0001
Total	0.4502	55	

$F_s = 148.0843$

$\alpha = .001$ 99.9% Confidence

$F_c = 3.44$

There is a significant difference in at least two means. Further analysis is made using Scheffe's interval.

H_0: $u_1 - u_2 = 0$

H_1: $u_1 - u_2 \neq 0$

$$(\overline{X}_1 - \overline{X}_2) \pm \sqrt{3.44} * \sqrt{.0001} * \sqrt{\frac{29}{56} 2}$$

$$(X_1 - X_2) \pm .018875$$

Note that H_0 cannot be rejected for F100F, F101B, F102A, F104G, F105D, and OV10A.

A significant difference exists in some mean simulator/flight ratios at the 99.9% confidence level. For aircraft with similar performance capability, the difference in means is not significant.

Table 4-7

Simulator/Flight Ratio by Aircraft Type

Code	Value Label	Sum	Mean	Std Dev	Sum of Sq	N
1	A7	1.714	0.214	0.004	0.000	8
2	A37	0.095	0.048	0.	0.000	2
3	B52	0.335	0.168	0.000	0.000	2
4	C130	0.209	0.209	0.	0.	1
5	F100F	0.060	0.060	0.	0.	1
6	F101B	0.060	0.060	0.	0.	1
7	F102A	0.060	0.060	0.	0.	1
8	F104C	0.217	0.217	0.	0.	1
9	F104G	0.060	0.060	0.	0.	1
10	F105D	0.119	0.060	0.	0.000	2
11	F105G	0.048	0.048	0.	0.	1
12	F106A	0.226	0.075	0.024	0.001	3
13	F111D	0.209	0.209	0.	0.	1
14	F111F	0.644	0.215	0.005	0.000	3
15	F4C	0.427	0.213	0.006	0.000	2
16	F4D	1.055	0.211	0.003	0.000	5
17	F4E	0.209	0.209	0.	0.	1
18	FB111	0.217	0.217	0.	0.	1
19	HH1H	0.060	0.060	0.	0.	1
20	KC135	0.168	0.168	0.	0.	1

Table 4-7 (continued)

Code	Value Label	Sum	Mean	Std Dev	Sum of Sq	N
21	02A	0.223	0.074	0.025	0.001	3
22	OV10A	0.040	0.040	0.	0.	1
23	RF101C	0.060	0.060	0.	0.	1
24	RF4C	0.419	0.209	0.000	0.000	2
25	T33A	0.207	0.103	0.	0.000	2
26	T38A	0.605	0.302	0.000	0.000	2
27	T39A	0.103	0.103	0.	0.	1
28	U100	0.183	0.061	0.	0.000	3
29	VT29C	0.302	0.302	0.	0.	1
30	VT29D	0.479	0.479	0.	0.	1
Total		8.810	0.157	0.090	0.003	56

For example, no difference in mean simulator/flight ratio exists between F101B, F102A, F104C, F105D, F105G and F101B. However, there is a significant difference between the above aircraft and heavier aircraft (VT29D,KC135, FB111).

A third ANOVA analyzed instructor pilot/first pilot time by type of aircraft (Reference Table 4-8).

ANOVA Table

	Sum of Squares	Degrees of Freedom	Mean Square
Between groups	66519064.000	29	2293760.8125
Within groups	18407273.250	26	707972.0469
Total	84926337.000	55	

$F_s = 3.2399$

$\alpha = .10$ 90% Confidence

$F_c = 1.65$

Note: Cannot reject H_0. There is no significant difference between means. That is, the type of aircraft is not a factor in determining IP/FP time. This statement is true with 90% confidence.

Table 4-8

IP/FP Time by Aircraft Type

Code	Value Label	Sum	Mean	Std Dev	Sum of Sq	N
1	A7	12350.000	1543.750	750.263	940263.500	8
2	A37	2527.000	1263.500	659.731	435244.500	2
3	B52	2111.000	1055.500	193.040	37264.500	2
4	C130	760.000	760.000	0	0	1
5	F100F	3101.000	3101.000	0	0	1
6	F101B	1082.000	1082.000	0	0	1
7	F102A	2292.000	2292.000	0	0	1
8	F104C	1399.000	1399.000	0	0	1
9	F104G	2103.000	2103.000	0	0	1
10	F105D	4886.000	2443.000	1821.507	317888.000	2
11	F105G	750.000	750.000	0	0	1
12	F106A	7564.000	2521.333	789.952	248048.672	3
13	F111D	2096.000	2096.000	0	0	1
14	F111F	4567.000	1522.333	567.804	644802.664	3
15	F4C	12432.000	6216.000	0	0	2
16	F4D	6583.000	1316.600	323.293	418073.199	5
17	F4E	1864.000	1864.000	0	0	1
18	FB111	1828.000	1828.000	0	0	1
19	HH1H	3743.000	3743.000	0	0	1
20	KC135	2376.000	2376.000	0	0	1
21	02A	5279.000	1759.667	774.571	199920.672	3

Table 4-8 (continued)

Code	Value Label	Sum	Mean	Std Dev	Sum of Sq	N
22	OV10A	1388.000	1388.000	0	0	1
23	RF101C	3266.000	3266.000	0	0	1
24	RF4C	3068.000	1534.000	1110.158	232450.000	2
25	T33A	3519.000	1759.500	485.782	235984.500	2
26	T38A	3311.000	1655.500	368.403	135720.500	2
27	T39A	1416.000	1416.000	0	0	1
28	U100	8066.000	2688.667	1667.575	561612.688	3
29	VT29C	2161.000	2161.000	0	0	1
30	VT29D	4940.000	2948.000	0	0	1
Total		112828.000	2014.786	1242.624	18417273.250	56

CHAPTER V

PREDICTION MODELS FOR IMPROFICIENCY COST

A general prediction model was developed using accident data for 1974 and 1975. The model was developed to predict the expected improficiency cost, given the allocations of flying and simulator time. Data represent post implementation of energy conservation measures (ECM). Although 1973 was the first year of ECM, it was not included in the development of the prediction model. The year 1973 was considered to be a transition period in that full implementation of ECM was not realized and consequently, significant variations exist between 1973 and later years. 1974 and 1975 were assumed to represent the steady state of ECM implementation.

The model will determine the expected pilot proficiency level in terms of pilot error cost (pilot improficiency). The general model was developed using the observed mixes of simulation hours and flying hours per each three month period during 1974 and 1975. These figures are regressed against the corresponding pilot error costs for the same three-month periods. By using multiple regression techniques, the model will determine the relationship between actual flying

time (AFT_i), simulated flying time (SFT_i), and pilot proficiency (P_i) in terms of dollar amounts.

$$\text{Prediction Model: } P_i = A_i + B_1 (SFT_i) + B_2 (AFT_i) + e$$

A_i = A constant in the prediction model, determined by the data in the regression technique. A_i is the point of intersection of the regression plane and the y-axis.

e = Innate differences in ability, assumed constant in this model.

Table 5-1 gives data for 1974 and 1975 used to develop the general model. Figure 5-1 graphically depicts the simulation, flying and cost data.

Table 5-1

Pilot Error Costs, Simulator Hours, and Flying Hours
Data Summary (1974-1975)

	Cost of Pilot Errors	Simulator Time (Hrs)	Flying Time (Hrs)	Simulation Flight Ratio
Jan-Apr 74	$24,545,253	234,915	1,163,146	.20197
May-Aug 74	20,669,475	181,642	1,002,292	.18123
Sep-Dec 74	21,441,630	192,296	1,034,463	.18589
Jan-Apr 75	16,915,337	259,868	1,431,496	.18154
May-Aug 75	17,721,433	266,386	1,441,609	.18478
Sep-Dec 75	17,301,189	266,898	1,472,084	.18130

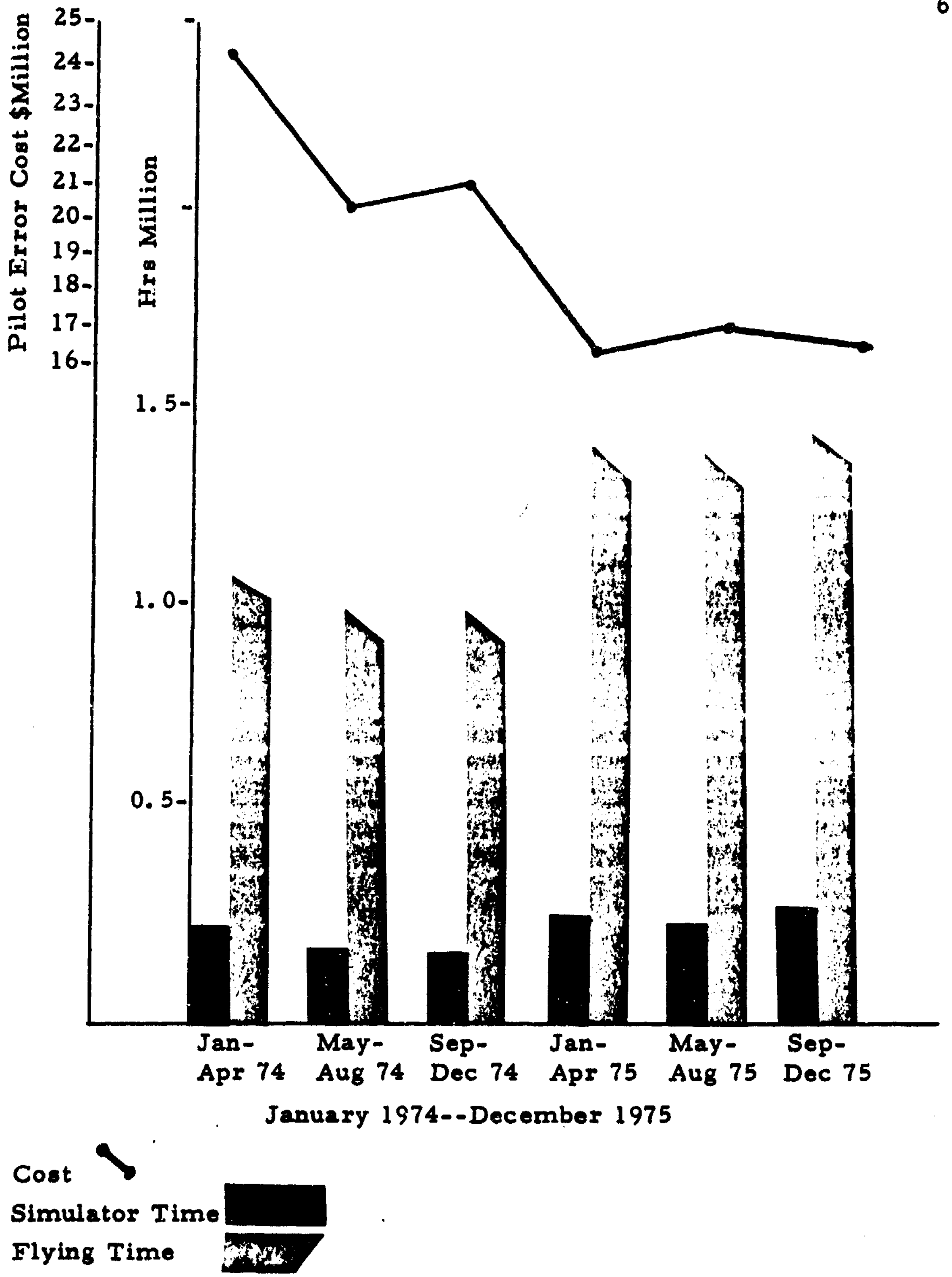

Figure 5-1

Pilot Error Costs, Simulator Hours, and Flying Hours Data Summary (1970-1975)

MULTIPLE REGRESSION ANALYSIS

Regression Analysis: (Reference Table 5-2). Regression of simulator time and flight time on pilot error cost (improficiency cost) results in the following sample model.

$$P_i = A_i + B_1\ (SFT_i) + (-)\ B_2\ (AFT_i)$$

$$P_i = 29.11850 + 213.02146\ (SFT_i) - 47.02118\ (AFT_i)$$

where:

P_i = improficiency cost

SFT_i = simulator hours

AFT_i = flight hours

A_i = constant

The model indicates that as the flight hours increase (SFT_i remains constant), pilot proficiency increases as indicated by reduced pilot error cost; as simulator hours increase (AFT_i remains constant) the pilot error cost increases.

The model will predict pilot error cost for the range of observed data with 95% confidence. T-tests on the individual regression coefficients, B_1 and B_2, follows (Reference Figure 5-2):

*$B_1 : t_s = 10.6038$ $\qquad t_c = \pm 2.776$

*$B_2 : t_s = -13.264$ $\qquad \alpha/2 = .025 \qquad df = 4$

*Values taken from Table 5-2.

Table 5-2

Regression Analysis

Coefficient of Determination (R^2):	0.9887711
Standard Error of the Estimate, S:	0.4097839

Analysis of Variance Table

Source	Variation(s)	DF	Mean Square	F
Explained	44.359726	2	22.179863	132.083660
Error	0.503769	3	0.167923	
Total	44.863495	5		

Variable	Coefficient	Standard Error	T Ratio
0	29.11805	1.13880	25.56903
2	213.02146	20.26774	10.51037
3	-47.02118	3.57642	-13.14756

Note: Model and analysis developed using MLREG computer program.

See Statistical Tests

Figure 5-2: t-Test of individual B_is

Figure 5-3: F-Test on overall regression

t-Test of Individual B_is

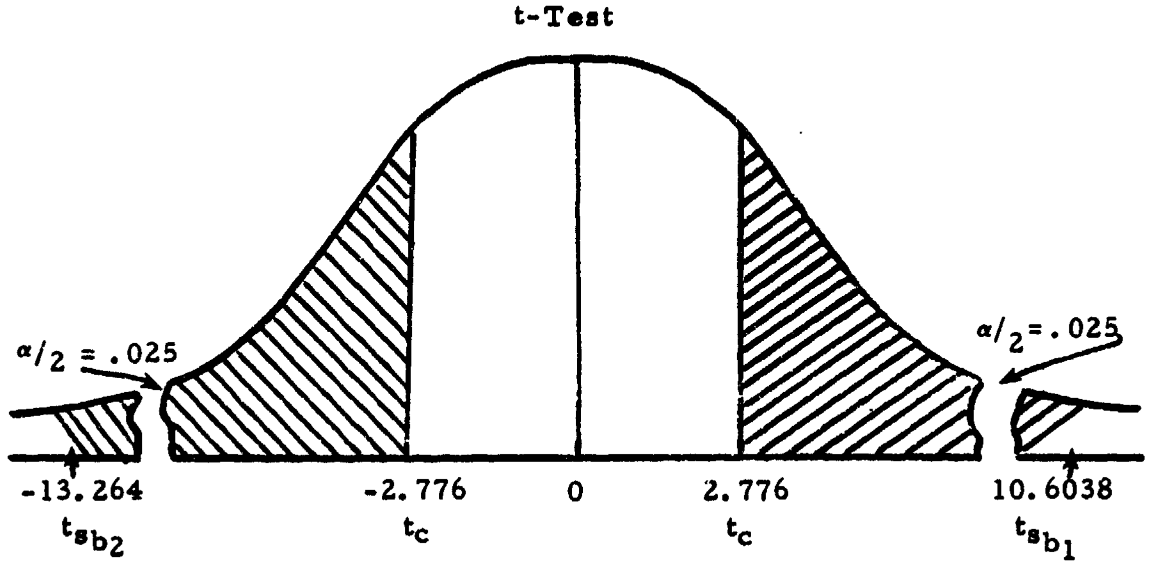

Figure 5-2

t-Test: Linearity Test of Statistical Data

$t_c = \pm 2.776$

$\alpha/2 = .025$

$df = 4$

$H_0: b_i = 0$

$H_1: b_i \neq 0$

$|t_c| < |t_s|$ Reject H_0, there is a linear relationship between simulator hours, flying hours and pilot error cost.

F-Test on Overall Model

$H_0: B_1 = B_2 = 0$

$H_1: B_1 \neq B_2 \neq 0$

$\alpha = .05$

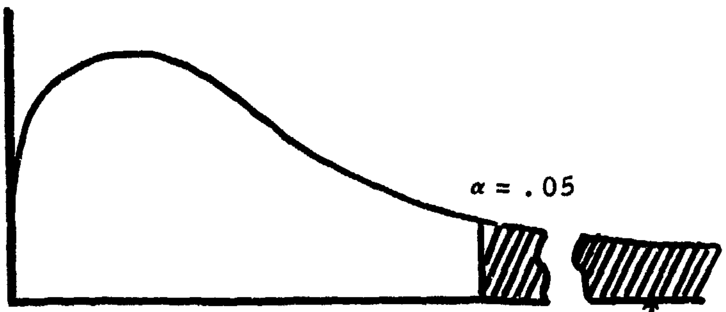

Figure 5-3

F-Test: A Test on Overall Regression

$^*F_s = 132.08$

$F^{2}_{c3} = 9.55$

$\alpha = .05$

$F_c < F_s$ ∴ Reject H_0, there is significant variability between the coefficients B_1 and B_2. The confidence level is 95%.

*Note: F_s value extracted from computer printout.

The preceding statistical tests were selected in order to reach an objective decision as to whether the hypotheses are confirmed by the set of given data. In the decision making processes the level of significance (α) was set at = .05. That is, the probability of accepting the null hypothesis (H_0) is 5% or less. In both the t-Test and F-Test, the H_0 was rejected. The results indicated that the level of confidence, beta ($\beta = 1 - \alpha$), was 95% or greater, which indicated that the alternative hypothesis (H_1) can be accepted with a confidence level of 95%. Specifically, the results show that significant linearity exists between the individual B_is in the t-Test. Further, the F-Test shows that the overall mode is significant. The conclusion is that the prediction model is significant (reject H_0) and can be used with at least 95% confidence to predict the values of the associated variables for the range of data selected for this research.

Test of General Prediction Model

To test the accuracy of the general model, a second model was developed using quarterly data from January 1974 to August 1975. The model was then used to predict the improficiency cost for the period September-December 1975, given the simulator and flying hours.

The model developed is shown below:

$$P_i = A_i + B_i\ (SFT_i) + B_2\ (AFT_i)$$

$$P_i = 29.87 + 220.90\ (SFT_i) - 49.20\ (AFT_i)$$

$$P = 29.87 + 220.90\ (.2669) - 49.20\ (1.472)$$

$$P = 29.87 + 58.96 - 72.43$$

$$P = 16.4 \text{ million dollars}$$

The value for P compares favorably with the actual improficiency cost of 17.3 million dollars for the predicted period. Part of the .9 million dollar difference can be explained by the test model's reduced accuracy due to the smaller sample size. Additionally, some error was incurred due to rounding numbers to two decimal places.

MODEL UTILITY

The general prediction model can be used by interested officials to predict the expected improficiency cost given any ratio of simulator to flying time within the range of those used to formulate the model. The model is applicable to budget planners in estimating the segment of expense associated with aircraft accidents. The model may also be used to further enhance the flying safety program by predicting improficiency based on varying amounts of simulator and flying time.

Prediction Model for A-7 Aircraft

An attempt was made to develop a regression model to predict the cost of pilot improficiency for specific aircraft, given simulator/flight ratio and IP/FP time. With the exception of A-7 aircraft, models computed were insignificant due to the limited number of observations (aircraft accidents) of like aircraft.

The A-7 prediction model was developed using accident data for 1974 and 1975. The total variation (R^2) explained by the model was 51.48%. However, the F-Test confirmed that the overall model is significant at the 99% confidence level. A summary of the results is given below:

$R_2 = 0.5148065$

$S = 4.2457174$

ANOVA Test

Source	Variation (ss)	DF	Mean Square
Explained	248.642056	2	124.321028
Error	234.339512	13	18.026116
Total	482.981564	15	

F-Test on Overall Model

$H_0: B_1 = B_2 = 0$ $\quad H_1: B_1 \neq B_2 \neq 0$ $\quad \alpha = .01$

$F_s = 6.896717$ $\quad F_c = 6.70$

Reject H_0

Variable	Coefficient	Std Error	T Ratio
A_i	0.32068	2.99920	0.10692
B_1	29.74142	19.10356	1.55685
B_2	523.91187	311.72696	1.68068

A-7 Model

$$P_i = A_i + B_1 (SFR_i) + B_2 (T_i)$$

$$P_i = 0.32068 + 29.74142 (SFR_i) + 523.91187 (T_i)$$

where:

P_i = improficiency cost

SFR_i = simulator/flight ratio

T_i = IP/FP time.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

There has been a decrease in total flying proficiency since the implementation of energy conservation measures in 1972. The decrease in pilot proficiency as measured by the cost of pilot error accidents shows that the average cost of pilot errors increased by $472,810 from Period I (pre-ECM) to Period II (post-ECM). During the same periods, total flying time was reduced by 4,548,481 hours and simulator hours increased by 854,357 hours. The ratio of flight time to simulator time changed from 14.9:1 for Period I to 5.4:1 in Period II. Simultaneously, other indicators of pilot proficiency such as the number of fatalities and the number of aircraft destroyed significantly increased in Period II. The conclusion is that the present level of flight time is insufficient to maintain the level of proficiency demonstrated in Period I.

In examining the type of errors committed in Period I versus Period II, it is clear that during Period I, the type of errors committed were less costly in nature when compared with Period II. The implications are that reduced exposure to actual flight resulted in a reduction of the total number of errors, but the errors committed were

of a more serious consequence. It is axiomatic that the only way to totally reduce errors is to cease flying, however, management has determined that pilot proficiency would be maintained at the pre-ECM level. This means that the present level of flight time must be increased, in that simulators have not proven to be a viable alternative to actual flight for maintaining pilot proficiency.

In evaluating the 1974 and 1975 variables related to pilot error accidents (IP/FP time, phase of flight, type of aircraft, simulator/flight ratio), the descent and landing phase accounted for 42.9 percent of all accidents. The conclusion is that simulators have failed to provide the necessary realism in training and/or learning transfer to maintain the desired level of pilot proficiency particularly in this phase of flight.

An analysis of variance between types of aircraft and simulator/flight ratio reveals that there is no significant difference between F-102s, F104Gs, F-105s, F-100s, F-101Bs, and F-104Cs. The conclusion is that similar requirements for simulator and flight time exist for fighter type aircraft. On the contrary, significant differences exist between KC-135s and FB-111s for example. Such differences indicate that the simulator/flight ratio requirements vary among some aircraft, based primarily on technological sophistication. The implications are that a tradeoff is possible between technological sophistication in aircraft and simulator/flight ratio.

Based on the analysis of pilot error accidents for Period I and Period II, the following recommendations are submitted:

1. The current level of flying must be increased to maintain flying proficiency at the pre-ECM level.

2. Simulator hours, although a significant contributor to pilot proficiency, must be viewed as a supplement to flight vis-a-vis a substitute for flight.

3. Further study is recommended to determine the cost/benefit tradeoff between simulation and actual flight.

4. An additional study should be made after simulators currently in R&D have become operational.

5. The allocation of flying and simulator hours at DOD level should be made after management has determined an acceptable level of pilot improficiency. The model presented in this thesis should assist in arriving at this decision.

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